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OPTICAL DATA COPY PROTECTION

FIELD OF THE INVENTION

The present invention is directed to copy protection of optical recording media and specifically to the protection of data recorded on optical disks.

BACKGROUND OF THE INVENTION

Optically readable digital storage media, such as music and software CD's and video DVD's, provide inexpensive ways to share and disseminate digital information, making such media the media of choice among both producers and consumers. This is clearly evident as CD's have nearly replaced cassette tapes and floppy disks in the music and software industries and DVD's have made significant in roads in replacing video cassette tapes in the home video industry. Because of the high demand for such optical media and because of the ease and low cost of reproduction, counterfeiting has become prevalent.

A variety of copy protection techniques and devices have been developed to limit the unauthorized copying of optical media. Among these techniques are analog Colorstripe Protection System (CPS), CGMS, Content Scrambling System (CSS) and Digital Copy Protection System (DCPS).

Analog CPS (also known as Macrovision) provides a method for protecting videotapes as well as DVDs. The implementation of Analog CPS, however, may require the installation of circuitry in every player used to read the media. Typically, when a disk or tape is "Macrovision Protected," the electronic circuit sends a colorburst signal to the composite video and s-video outputs of the player resulting in imperfect copies. The use of Macrovision may also adversely affect normal playback quality.

With CGMS, the media may contain information dictating whether or not the contents of the media can be copied. The device that is being used to copy the media must be equipped to recognize the CGMS signal and also must respect the signal in order to prevent copying.

The Content Scrambling System (CSS) may provide an encryption technique that is designed to prevent direct, bit-to-bit copying. Each disk player that incorporates CSS is provided with one of four hundred keys that allow the player to read the data on the media but prevents the copying of the keys needed to decrypt the data. However, the CSS algorithm has

been broken and has been disseminated over the Internet, allowing unscrupulous copyists to produce copies of encrypted disks.

The Digital Copy Protection System (DCPS) provides a method whereby devices that are capable of copying digital media may only copy disks that are marked as copyable. Thus, the disk itself may be designated as uncopyable, however, for the system to be useful, the copying device must include the software that respects the "no copy" designation.

Each of these copy protection techniques, and others that may be available, may make it more difficult to copy material from optical media, and may deter the casual copyist. However, these techniques may be easily circumvented by the unscrupulous copyist who is intent on making digital copies of a disk.

SUMMARY OF THE INVENTION

In one illustrative embodiment, a method of authenticating optical storage media is disclosed. A locus on an optical storage medium is read and a first set of data is received from the locus. The locus is then re-read and a second set of data is read from the locus, the second set of data being different from the first set of data.

In another illustrative embodiment an optical disk is disclosed. The optical disk includes a substrate and a data track disposed on the substrate. A light-sensitive compound is disposed on at least a portion of the disk and cooperates with the data track to alter the data upon excitation with a suitable stimulus.

In another illustrative embodiment, a method of treating an optical storage medium is disclosed. Data is recorded onto the optical storage medium and a light-sensitive compound is applied to the medium. At least a portion of the light-sensitive compound is selectively activated.

In another illustrative embodiment an optical recording medium is disclosed. The optical recording medium includes stored data and means for altering, upon re-reading, data that is read from a locus on the medium.

In another illustrative embodiment, an optical recording medium is disclosed. The medium include a data track including readable data. At least a portion of the output is altered predictably upon re-reading.

In another illustrative embodiment, a method of authenticating an optical storage medium is disclosed. The medium has a first plane including data and a second plane having a light-sensitive compound. The method includes reading data from the first plane, exciting the light-sensitive compound in a second plane and reading data from the second plane.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of one type of optical reader that may be used with an embodiment of the present invention.

Figure 2 is an enlarged cross-sectional illustration of an optically readable medium including recorded data.

Figure 3 is a cross-sectional illustration of an optically readable medium including recorded data and a representation of the binary data that is read when the medium is sampled.

Figure 4 is a cross-sectional illustration of an optically readable medium including recorded data and a representation of the binary data that is detected when the medium is sampled.

Figure 5 is a cross-sectional illustration of the optical medium of Figure 4 including a representation of the binary data that is read when the medium is re-read.

Figure 6 is a cross-sectional illustration of an optical medium including a representation of binary data that is detected when the medium is re-read.

DETAILED DESCRIPTION

The present invention is directed to protecting optically recorded media from being reproduced or copied. The invention provides for the altering of the digital data output from a section of the media in a manner that allows the data to be read without requiring alterations to the hardware, firmware or software used in optical media readers while preventing reproduction of the medium. This may be accomplished by employing a light-sensitive compound on the disk that reacts upon excitation from the light within a conventional optical reader in a manner to selectively alter data read by the reader.

"Optical Storage Media" refers to media capable of storing digital data that may be read by an optical reader.

"Light Sensitive Compound" refers to a compound that responds to irradiation with light.

"Light Absorptive Compound" refers to a compound that absorbs light in response to excitation.

"Light Emissive Compound" refers to a compound that emits light in response to excitation.

"Re-read" refers to re-sampling a portion of the data recorded on an optical medium after it has been initially read.

"Fluorescent Compound" refers to a compound that radiates light in response to excitation by electromagnetic radiation.

"Phosphorescent Compound" refers to a compound that emits light in response to excitation by electromagnetic radiation wherein the emission is delayed from the time of excitation.

"Recording Dye" refers to a chemical compound that may be used with an optical recording medium to record digital data on the medium.

"Security Dye" refers to a compound that may provide or alter a signal to protect the data on an optical storage medium.

"Active Light-Sensitive Compound" refers to an active form of a light-sensitive compound, as some light-sensitive compounds may exist in both active and inactive states.

"Active Security Dye" refers to the active form of a security dye, as some security dyes may exist in both active and inactive states.

"Activate" refers to transforming a compound from an inactive to an active state.

"Non-Destructive Security Dye" refers to a security dye that does not render optical media permanently unreadable.

"Reader" refers to any device capable of detecting data that has been recorded on an optical medium.

Copy protection schemes that are available today typically require changes to the hardware that is used to read, and potentially copy, the media, or these schemes require the use of data encryption that may be broken by those who are determined to do so. The present invention may provide a technique that requires neither encryption nor hardware changes but

may incorporate a physical change in the media itself. The invention may provide for a first data set when the media is sampled by a reader and then may provide for an alternative data set when the media is re-read by the reader.

In one aspect of the invention, a specific locus on an optical storage medium is read, and the same locus is re-read again. Upon re-reading, the data that is read from the locus is different from that of the initial reading. This may be accomplished by incorporating a compound into or onto the media. Upon exposure to light of a wavelength, the compound may provide no immediate response. However, upon re-reading by the reader, which occurs later in time, the compound emits light at an intensity and wavelength sufficient to alter the data that is read from the media. In one aspect, as will become apparent, the data is blocked upon re-reading.

In another aspect, an optical disk that includes a substrate with a data track disposed on the substrate includes a non-destructive light-sensitive compound that has been disposed on at least a portion of the disk.

In another aspect of the invention, a light-sensitive compound is applied to an optical storage medium on which data has been or will be recorded. At least one portion of the light-sensitive compound may then be selectively activated so that the light-sensitive compound provides delayed light emission or absorption in response to excitation with a light source.

In another aspect, a method of authenticating optical storage media is provided wherein data is sampled from a first track of an optical medium with the first track being located in a first plane, and at the same time, exciting a light-sensitive compound that resides in a different, second plane on the optical medium. The output produced from the light-sensitive compound in the second plane is then sampled from the optical medium.

In another aspect, a data track containing readable data is re-read and at least a portion of the data is predictably altered upon re-reading.

The invention may be useable with conventional optical media. For example, a DVD disk incorporating the invention may provide protection when being read by an "off the shelf" DVD player. In addition, the invention may be incorporated into mass production techniques that are currently used to produce, for example, CDs and DVDs, and may not require changes to production line plant and equipment. Figure 1 provides a schematic representation of a conventional CD reader that may be used in conjunction with the invention.

Referring to figure 1, a light source 10, typically a laser diode, emits light of a specific wavelength, for example, 780 nm. The light passes through defraction grating 20 where it splits into a primary beam 30 and secondary beams 31 and 32. Each of these beams then passes through polarizing beam splitter 40 which polarizes them by 90 degrees. Each of these beams then passes through collimating lens 50 and then through ¼ waveplate 60. ¼ waveplate 60 converts the light into circularly polarized light. The polarized, collimated light beams then pass through objective lens 70 and are focused onto optical disk 80, such as a CD, that is spinning at a variable rate to provide for constant velocity of the track, regardless of the laser's position on the disk. Any light that is reflected back from the disk (see description below) passes back through the objective lens 70 and through the ¼ waveplate 60 which further polarizes the light so that it is now polarized perpendicularly in comparison to the polarization of the first light beam prior to its initial passage through the ¼ waveplate 60. The reflected beam then passes back through the collimating lens 50 and because of its change in polarization is now reflected off of beam splitter 40 rather than passing through beam splitter 40. The reflected beam is then focused through concave lens 90 and further through cylindrical lens 100, which aids in the tracking of the light beam along the data track. Finally, the reflected light beam impinges upon photodetector 110 where the signal can be detected and processed.

Although one type of optical reader is described, the present invention is not limited in this respect and other suitable optical readers may be employed in conjunction with the invention. The above description, therefore, is merely illustrative of a typical optical reader. Those skilled in the art will recognize various alternatives for an optical detector, whether embodying some or all of the elements described above, that may be employed with the present invention.

An enlarged view of the CD is illustrated in figure 2, which shows a cross-sectional view (not to scale) of a track on the CD. The CD substrate 210 is typically made from a polymer such as polycarbonate, however, other suitable materials may be used. Data is recorded on the CD by forming a series of pits 220 and lands 230 in the substrate of the disk. Pits and lands may be formed using any suitable technique including injection molding of the features themselves or, alternatively, using a recording compound and a writing laser. If a recording compound is used, data may be written to the medium using a laser that is designed to heat the recording compound to a point where adjacent polymer material is deformed to form the pits and lands. Typically,

for an audio CD, each pit is about ½ micron wide and anywhere from about 0.8 to 3.5 microns long. However, it should be appreciated that the present invention is not limited in this respect and other methods of recording and /or sharing data on the CD may be employed.

The pits and lands are typically coated with a reflective layer 240, of, for example, aluminum, which is then coated by a protective layer 235, typically acrylic. If desired, the acrylic layer may be covered by a label, 250. In operation, the light beam 30, typically at a wavelength of 780 nm, passes through the surface of the polycarbonate substrate 210 where it becomes more sharply focused due to the high refractive index of the polycarbonate. The high refractive index may also alter the wavelength of the light, for example, from 780 nm (infrared) to about 500 nm (green). The beam is focused on the reflective surface 240 where it is highly reflected by the lands 230, and less directly reflected, or scattered, by pits 220. The pits are typically formed at a height of about ¼ of the wavelength of the light passing through the polycarbonate. Thus, light that is reflected from a land travels about ½ wavelength farther than light that is reflected from a pit, resulting in light reflected from a pit being out of phase with light reflected from a land. The two waves will therefore cancel each other, resulting in no light being reflected back to the detector.

Figure 3 illustrates schematically one method of transforming a light beam reflected off of a CD into digital information. By setting a threshold level of reflectance, transitions between pits and lands may be detected at the point where the signal generated from the reflectance crosses a threshold level. Whenever the threshold level is crossed, i.e., a transition between a pit and a land or between a land and a pit is detected, a binary code of 1 is read. At all other intervals, a 0 is detected. Thus, both pits and lands may actually represent a series of 0's; it is the transition that represents a 1. In this manner, binary information may be read from the disk.

As may be apparent to those skilled in the art, the data on a disk may be transformed using an eight to fourteen modulation (EFM) convention. EFM provides a process whereby 1's need not be written consecutively, as this would require extremely small pits or lands with frequent transitions that might result in numerous errors. In addition, EFM specifies that at least two and no more than 10 0's appear between any pair of 1's. In addition, three merging bits are placed between each fourteen bit set to help further minimize errors. After detection, each fourteen bit piece of data is converted into an eight bit binary word. The fourteen bit process that is physically recorded onto the optical medium may contain no more than ten and no fewer

than two 0's between each pair of 1's, but can represent any eight bit word. Although an EFM protocol has been described, the present invention is not limited in this respect and other protocols may be implemented. In addition, no such protocol need be employed. Thus, the above-described EFM is merely illustrative of conventional manipulation of data combined on a CD.

Figure 3 shows how the raw bit data may be read from a CD track as it passes under the light source. For example, referring again to figure 3, transition points may be seen at points A, B, C and D. Each of these points corresponds to a transition in the medium between a pit and a land or a land and a pit. At each of these transition points, the signal generated from the reflected laser crosses the threshold and a 1 is read at each of these transition points. At non-transition points, a series of 0's is read.

The method and apparatus of the present invention may provide producers and distributors of digital data with a technique that aids in the prevention of reproducing, for example, software, audio and video optical media. Some of the formats with which the invention may be useful include, but are not limited to, CD Audio, CD-ROM, CD-G, CD-i, CD-MO, CD-R, CD-RW, DVD, DVD-5, DVD-9, DVD-10, DVD-18 and DVD-ROM.

In one embodiment, the invention may provide copy protection by changing the output from an optical medium upon re-reading of a locus on the medium. The location that is re-read may be of any size or type and may include, for example, a single bit, a byte, a frame, a block, a sector or any other selection that is recorded or will be recorded on the medium. In addition, any number of different locations may provide a change in output upon re-reading.

Many conventional optical media readers such as CD and DVD readers may be capable of oversampling a particular locus on the optical medium to reduce the likelihood of playback errors. Oversampling may occur immediately after an initial sampling or may be delayed. Software written on the optical medium may direct the reader to resample a particular set of data one or more times, or a reader may be pre-programmed to resample the media a number of times without any additional input from software on the media. For example, one way in that a CD player may resample data is by oversampling an audio disk several times in order to reduce errors and ensure adequate reproduction. A data set on a CD or DVD may be oversampled any number of times, for example, 4X or 8X, and the readings may be compared so that errors may

be eliminated or minimized. In one embodiment, the invention may incorporate such oversampling.

The output at a particular locus may be changed by including an additional compound in the medium. For example, on an initial reading, the compound may have little or no effect on passing light and therefore underlying data is read and interpreted as originally recorded. However the passing light may influence the compound and change its properties so that upon re-reading, the signal that is received by the detector is different from that which was received upon initial sampling. The compound may be a light sensitive compound. For instance, the added compound in the medium may become reflective within a timeframe that provides for reflectance of the light beam upon resampling. Alternatively, a compound may provide for delayed emission or absorbance of light and therefore may be used to alter the signal either positively or negatively.

In one example, data recorded on an optical medium instructs the optical reader to re-read a particular locus on the medium. For example, the reader may be instructed to re-read a sector on the disk. The medium may contain areas that include a light sensitive compound, such as a fluorescent or phosphorescent compound. This light-sensitive compound may be chosen so that it is excited by a wavelength that is typically used by a reader on which the particular medium is played. For example, in the case of a CD reader, the light-sensitive compound may be chosen to absorb at about 780 nm. The light-sensitive compound may be placed anywhere in or on the medium and in one aspect may be strategically placed in the light path between the data recorded on the optical medium and the detector that is used to read the reflected light off of the medium. If, upon re-reading, a reading from the light-sensitive compound is detected, access to the data on the media may be provided. If the response upon re-reading is the same as upon initial sampling, indicating absence of the light-sensitive compound, further access may be denied.

Protection may be also provided by using a light-sensitive compound to record data at a particular locus required for the optical media to be operable. The light-sensitive compound may be placed in a different plane in the media, so that in order to be optimally read, the focal length of the optical system should be adjusted. Software included on the disk may direct the optical reader to alter its focal length appropriately, however, when an attempt is made to

reproduce the media, the copyist may be unable to reproduce the required data on media that does not include properly placed light-sensitive compound.

The light-sensitive compound may be placed in the medium as close to the recorded data as possible. This may provide, for example, a more precise focusing of the light beam in the area of the light-sensitive compound as the substrate material of which the medium is composed may serve as a lens to further concentrate the light beam at the point where the data has been recorded. Thus, if the light beam focuses on the appropriate plane in which the recorded data lies, it may not be fully focused on the light-sensitive compound that lies in a plane that is a distance from the recorded data. To minimize this difference in focal length, the light-sensitive compound layer may be placed directly over the recorded data. Upon a first pass of the light beam over the locus of the medium containing the light-sensitive compound, the compound may absorb some of the light, however, some of the light may pass through the compound striking the recorded data on a track in the medium, and reflecting back up through the light-sensitive compound to a detector where the data may be read, as it would be in the absence of the light-sensitive compound. However, if the reader has been instructed to re-read this particular locus, the reader will return to the same area on the medium in order to re-read the same set of data. By this time however, the light-sensitive compound may be emitting or reflecting or absorbing at a wavelength detected by the reader, and the signal produced from the detector may differ from that produced upon initial sampling, as areas that were initially of low reflectance, e.g., pits in the recording medium, are now read as reflectant due to the emission from the light-sensitive compound. If the emission from the light-sensitive compound is sufficient to provide a signal above a threshold, the data output will be varied from that which was originally read upon initial sampling. Thus, at the same point on the track, the recorded data may be read differently, though predictably, depending on whether the data is being initially read or re-read.

Protection may also be implemented by changing the wavelength of light from a reader. For example, the recorded data on the media may include instructions for the reader to use a different light source having a different wavelength to sample a particular locus on the medium. If the proper light-sensitive compound is present at the proper location, it will provide a detectable signal in response to being irradiated with light of the different wavelength. In turn, this may allow for continued access to the disk. If there is no response at the different wavelength, then access may be denied.

In another embodiment, delayed fluorescent compounds or phosphorescent compounds, emitting at a detectable wavelength after a specific amount of time, may be used in combination with an instruction set recorded on the medium that instructs the reader to re-read a specific locus on the medium after a time delay approximately equal to the amount of time required for the light-sensitive compound to fluoresce. For example, if a light-sensitive compound exhibits a peak fluorescence 1 millisecond after excitation by the light source, the medium may include instructions to direct the reader to re-read the particular area of the medium after a 1 millisecond time period. If, at the 1 millisecond time period, the expected fluorescence signal is detected, the reader is instructed to continue reading the recorded data off of the medium. If the expected fluorescence is not detected, access to the data on the disk may be denied. In this manner, a medium that does not include the proper compound in the proper location may not provide usable data to someone trying to access the data on the medium. Therefore, if an attempt is made to copy the optical medium, for example, by bit to bit copying, much of the data that is recorded on the medium may be successfully transferred, however the light-sensitive compound may not be copied as it may only be activated upon re-reading and in a typical bit-to-bit copying utility, bits are systematically copied as they are read. Thus, the copy will be inoperable.

Furthermore, if the light-sensitive compound is, in fact, detected during the copying procedure, it may not be possible to reproduce the signal provided by the light-sensitive compound at the same location on the optical medium that holds the originally recorded data, as a single locus on a track cannot simultaneously hold two different data sets. Therefore, when an attempt is made to operate a copy of the medium, the reader will be instructed to initially sample a specific locus on the medium and then re-read the locus looking for a different response. The unauthorized copy, however, may be able to provide only one of the two required responses as the copying system may be capable only of writing a single data set to the specific locus on the medium. Even if the data represented by the light-sensitive compound is copied, it may not be copied to the correct location and thus the copy may remain inoperable.

In other embodiments, any combination of sampling and re-reading of one or more areas of the medium may be employed. For example, the reader may be directed to resample a location on the medium and then wait a sufficient time for fluorescence to degrade to

nondetectable levels and then take a sampling of the location and detect the signal received from the underlying data.

In another embodiment, the reader itself may be programmed or designed to resample and analyze specific areas on an optical medium prior to proceeding with reading the medium. In this manner, among others, it may be possible to copy protect the optically readable medium without including reading instructions on the medium itself.

In addition to using fluorescent light-sensitive compounds, other light-sensitive compounds, for example, dyes, pigments, phosphorescent compounds and light absorptive compounds may also be employed. For example, light absorptive compounds may be used to selectively absorb light that may be emitted by a reader or reflected off of particular areas of the medium. In this manner, the invention may allow a signal from a specific locus on a medium to be altered from one giving a reading above a threshold to one that reads below a threshold. Thus, the invention may be used to supply a positive signal where previously a negative one was present or alternatively, to supply a negative signal where previously a positive one was present. Various combinations of compounds may be used on the same or different media to produce both positive and negative changes in signal upon re-reading.

Light-sensitive compounds may be placed on the optical media in a number of ways. For example, a compound may be specifically placed in the optical path between a data set that has been recorded on the medium and the optical detector. It may be appropriate to place a light-sensitive compound over a larger area of the media than is necessary to provide a signal change. As it may be preferable for the light-sensitive compound to be active only upon re-reading, extraneous placement of the compound may not interfere with the initial reading of the recorded data. Furthermore, the light-sensitive compound may be distributed on the media in an inactive form and specific areas containing the compound may be activated later in time. For example, an inactive form of a delayed fluorescence compound may be spin coated across a portion of, or all of, the media. After the inactive form of the fluorescent compound has coated a portion of the media, it may be selectively activated at one or more locations to transform the compound into an active form.

In one embodiment, specific areas of the fluorescent compound may be activated by crosslinking. For some light-sensitive compounds, a laser may catalyze crosslinking of the inactive form of the light-sensitive compound and thus selectively transform it into an active

form. This technique may allow for localized compound activation and may provide for data alteration on a small scale, such as a single bit. This selective activation of various portions of the light-sensitive compound may be performed in a manner similar to that used to write data to a CD-R disk. In fact, the same device may be used to write data to a disk as well as to selectively activate portions of the light-sensitive compound. This may be done, for example, by using a variable power writer, or alternatively, it may be done by placing the light-sensitive compound on the disk in a plane that provides a different focal point than that provided by the recording dye. In this latter method, the focal point of the writing laser may then be altered to either affect the recording dye or the light-sensitive compound. If the data track on a specific medium is transferred to the medium by a physical means, for example, by injection molding, the activation wavelength of the light-sensitive compound may be chosen without regard to recording dyes.

In another embodiment, the light-sensitive compounds may be chosen from those having an excitation wavelength at or about the same wavelength used by a reader. For example, if a CD reader uses a laser diode emitting light at a wavelength of about 770-830 nm, then the light-sensitive compound may be chosen from a group having excitation wavelengths in the same range. In another embodiment, the light-sensitive compound may be chosen from a group of compounds having excitation wavelengths at about 630-650 nm, a wavelength typically used in a DVD reader. In another embodiment, compounds may be chosen that possess dual excitation wavelengths at both about 780 nm and about 530 nm. If such a dual wavelength compound is used, a single compound composition may be employed for use with media to be used with either a CD player or a DVD player. Such a compound composition may be either a mixture of different compounds or contain a single compound that exhibits multiple excitation wavelengths.

In another aspect, the compounds are chosen so that they emit at wavelengths that are the same or close to the same as the wavelengths that are detected by the readers. For example, for use with a CD, the light-sensitive compound may emit at about 780 nm and for use with a DVD, the light-sensitive compound may emit at a wavelength of about 650 nm. The chosen security dies may exhibit long term stability under typical optical media storage conditions and the compounds may be light fast and non-reactive. In addition, compounds may be chosen based on compatibility with the polymer or other material that is used to produce the optical media

substrate. Light-sensitive compounds may be chosen from those that exhibit stability for the expected lifetime of the optical media.

In one embodiment, the light-sensitive compounds are chosen from a group of dyes, specifically, cyanine dyes. These cyanine dyes include, among others, indodicarbocyanines (INCY), benzindodicarbocyanines (BINCY), and hybrids that include both an INCY and a BINCY. Hybrids may be, for example, mixtures of two different dyes or, in another embodiment, compounds that include both INCY and BINCY moieties. In one embodiment, the light-sensitive compound is a ratiometric compound having a linked structure with excitation ranges at both the CD and DVD ranges of about 530 and 780 nm. In a further embodiment, the dye is phosphorescent, having a time delay of about 10 milliseconds. Table 1 provides some of the dyes that may be useful with the invention.

Table 1

Dye Name/No.	CD/DVD	Excitation λ	Emission λ
Alcian Blue	DVD	630 nm	Absorbs
(Dye 73)			
Methyl Green	DVD	630 nm	Absorbs
(Dye 79)			
Methylene Blue	DVD	661 nm	Absorbs
(Dye 78)			
Indocyanine Green	CD	775 nm	818nm
(Dye 77)			
Copper Phthalocyanine	CD	795 nm	Absorbs
(Dye 75)			
IR 140	CD	823 nm (66 ps)	838nm
(Dye 53)			
IR –768 Perchlorate	CD	760 nm	786nm
(Dye 54)			

IR 780 Iodide (Dye 55)	CD	780 nm		804nm
IR 780 Perchlorate (Dye 56)	CD	780 nm		804nm
IR 786 Iodide (Dye 57)	CD	775 nm		797nm
IR 768 Perchlorate (Dye 58)	CD	770 nm		796nm
IR 792 Perchlorate (Dye 59)	CD	792 nm		822nm
1,1'-dioctadecyl-3,3,3',3'-tetramethylindodicarbocyanine perchlorate (Dye 231)	DVD	645 nm		665 nm
1,1'-dioctadecyl-3,3,3',3'-tetramethylindo tricarbocyanine Iodide (Dye 232)	DVD	748 nm		780 nm
1,1',3,3,3',3'-hexamethyl indodicarbocyanine Iodide (Dye 233)	DVD	638 nm		658 nm
DTP (Dye 239)	CD	800 nm	(33 ps)	848nm
HITC Iodide (Dye 240)	CD	742 nm	(1.2 ns)	774nm
IR P302 (Dye 242)	CD	740 nm		781 nm
DTTC Iodide (Dye 245)	CD	755nm		788nm

DOTC Iodide	DVD	690nm	718nm
(Dye 246)			
IR-125	CD	790nm	813nm
(Dye 247)			
IR-144	CD	750nm	834nm
(Dye 248)			

Light-sensitive compounds may be chosen from any compound or combination of compounds that serve to change the output signal from the medium upon re-reading. These compounds include delayed emission compounds, delayed absorbance compounds and other light sensitive compounds. For example, a layer in the medium that becomes reflective upon re-reading may also be useful in predictably altering the output of the medium.

Light-sensitive compounds may be placed on the optical media in various thicknesses dependent upon the application. For example, if a phosphorescent compound is applied by a spin coating process, it may be dissolved in ethyl lactate and the compound may overcoat the entire disk. The thickness of the compound layer may be controlled by varying, among other factors, the rotational speed of the media during this process. In one embodiment, the compound layer may be from 120 nm to less than 1 nm thick. The desired thickness of the compound layer that is applied may be a function of the absorption of the compound, the emission of the compound, the density of the compound and the structure of the media, as well as the properties of the reader that is used to read the data off of the media. In one embodiment, the compound may be applied at a thickness that is thin enough to allow transmission of light to adequately read the underlying data upon initial sampling while being dense enough to provide adequate fluorescence upon re-reading with the same reader.

A film thickness of from 50 to 160 nm has been found useful. It is preferred that the film thickness for a CD is in the range from about 70 nm to about 130 nm. While film thickness for a DVD is preferably in the range of from 50 nm to 160 nm, of course other suitable thicknesses may be employed.

In another embodiment, a 5 nm thick layer of a light-sensitive compound was spin coated onto a CD. At a laser diode wavelength of 780 nm, the absorption by the compound was about 61% and the delayed fluorescence of the compound was about 12%.

In addition to coating a light-sensitive compound onto the media, the compound may be spotted at specific locations on the media. Light-sensitive compound may be placed at any depth within or on the media and is preferably at a position in the media where the reader can adequately focus on the compound.

Figure 4 illustrates an embodiment of the invention using an optical medium similar to that described in figure 3. The digital output from the medium upon initial sampling is shown and is the same as the output from the medium illustrated in figure 3. The optical disk 200 shown in cross-section in figure 4 contains an additional light-sensitive compound layer 400 (not present in figure 3) which is distributed through the disk in a position that is close to reflective layer 240. Although the security layer 400 is shown disposed within the substrate 210, the present invention is not limited in this respect and the light-sensitive compound may be dispersed in any other suitable location. Light-sensitive compound 400 may be cross-linked, for example, by laser catalysis, at specific locations to provide a delayed fluorescence compound at the specific locations. Referring to figure 4, the location of activated compound is shown at locus 410. The data recorded on the disk, represented by a series of pits 220 and lands 230, is identical to that shown in figure 3. In operation, a focused light source used to read the optical disk passes through light-sensitive compound layer 400 and a portion of the light is instantaneously reflected back through light-sensitive compound layer 400 so that the data output upon an initial reading is identical to that shown in figure 3.

However, as is illustrated in figure 5, activated compound locus 410 is excited by the light and due to the compound's delayed fluorescence, emits light at a certain wavelength several milliseconds later, for example. Through instructions provided on the disk, the reader has been directed to re-read the same locus 410 on the disk shortly after its initial sampling. In one embodiment, as illustrated in figure 5, the reader re-reads locus 410 at about the time of the delayed fluorescence. The detector receives a different output than it does initially (as represented in figure 4) due to the light provided by the delayed fluorescence of activated light-sensitive compound locus 410. Light-sensitive compound locus 410 has been placed and activated to mask pit 270. Referring back to figure 3, showing a disk without light-sensitive

compound 400, as the track passes through the focused light beam, transitions representing 1's are detected at points A, B, C and D as the transition is made from pit to land or land to pit. The same response is received from the medium in the embodiment shown in figure 4, upon initial sampling. Referring now to figure 5, representing the response received upon re-reading, the light-sensitive compound at locus 410 is masking pit 270 and as the track passes through the light beam, a transition is still recognized at point A, but the transitions at points B and C are not detected because the emission of light from light-sensitive compound locus 410 blocks the transition and instead is read as a continuation of the land between points A and B. The signal generated across this span during re-reading does not cross threshold level, and the next transition to be detected is at point D. Thus, from points A to D the raw 14 bit data signal is read as 10010001001 prior to excitation of the light-sensitive compound at locus 410 (figure 4) and is read as 10000000001 upon re-reading when the light-sensitive compound at locus 410 has been excited by a previous pass of the laser (figure 5). The effective reflectance has been changed to simulate the removal of two transitions. In this manner, a different set of predictable data is read upon re-reading the same location that had been previously read by the same device. If the same location is re-read again after the compound emission has subsided, the initial reading of 10010001001 will be detected. The emission from the light-sensitive compound at locus 410 need not be as intense as that reflected back from a land but preferably is of adequate continuous intensity to prevent the signal from crossing the threshold.

Figure 6 illustrates an embodiment that uses a light absorbing compound to alter the data output from an optical medium. The data that has been recorded on disk 300 is identical to that shown in figures 4 and 5. Inactive light absorbing compound has been disposed in a layer 500 across a portion of disk 300. Locus 510 has been activated to make the light absorbing compound active at point F. Upon initially reading the disk, the reader detects data that is equivalent to that detected in figure 4, described above. Upon re-reading the data however, locus 510 has been excited by the previous pass of the laser, and, upon re-reading, absorbs light that is reflected off of land 530, and this light is therefore not detected. Whereas initially the data read from the track between points E and G was detected as 1000000001, upon re-reading the light absorbing compound has altered the data so that over the same section it reads 1001000001. Thus, the use of a light absorbing compound has added a transition where previously there was none.

By incorporating light-sensitive compounds having specific time delay in light emission and/or excitation and/or absorption at various wavelengths, with instructions to re-read specific areas on the media at time intervals based on the time delay, various copy prevention techniques may be formulated. Thus, any combination of sampling, re-reading and re-sampling of one or more locations on the media may be used. In addition, any combination of light sensitive compounds may be used to further vary the copy protection techniques.

Having thus described certain embodiments of the present invention, various alterations, modifications and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be within the spirit and scope of the invention. Accordingly, the foregoing description is by way of example only, and is not intended to be limiting. The invention is limited only as defined in the following claims and the equivalents thereof.